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WHY POTATOES RUN OUT

BUREAU OF PLANT INDUSTRY
27 APR 1926
MYCOLOGY

MOSAIC PLANT

HEALTHY PLANT

MOSAIC, leaf-roll, spindle-tuber, and related diseases are mainly responsible for the so-called degeneration or running out of potatoes.

Reductions in yield ranging from 15 to 70 per cent or practically a total loss in severe cases may result from these maladies.

The leading commercial varieties are susceptible to one or more of these diseases, which occur in the important potato-growing sections of the United States.

Aphids, or plant lice, spread these maladies from diseased to healthy plants. Consequently, it is impossible to produce or maintain disease-free plants by growing healthy stock in fields adjacent to fields with diseased potato plants. The selection of apparently healthy hills from partly diseased stock may result in diseased progeny.

Tubers from infected plants produce diseased progeny the following season. Infected tubers can not be distinguished from healthy tubers. Therefore, it is unwise to select tubers for seed merely on account of their good appearance in the bin.

Secure practically disease-free potatoes from reliable sources for seed. Plant in fields or plats isolated as far as possible from diseased fields and not cropped with potatoes the previous season. Try to keep such potatoes free from disease by careful field inspection and by roguing frequently any abnormal plants during the growing season.

Careful field inspection of plants is more important than any single procedure for obtaining information regarding insect-borne diseases. At this time these maladies can be detected and diseased plants removed, or if high percentages of diseased plants are found the stock can be condemned for seed purposes.

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WHY POTATOES RUN OUT[1]

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INTRODUCTION

RECENT investigations of potato diseases have resulted in obtaining considerable information which will prove helpful in the improvement of this crop. The evidence at hand indicates that seed-potato improvement is very largely a matter of disease control. In Farmers' Bulletin No. 1367, "Control of Potato-Tuber Diseases," the latest observations on tuber maladies are presented. Farmers' Bulletin No. 1349, "Increasing the Potato Crop by Spraying," presents information on spraying for the improvement of the crop. In the following pages the group of so-called virus or degeneration diseases of the potato, including mosaic, leaf-roll, spindle-tuber, streak, and curly-dwarf, will be considered with respect to symptoms, dissemination, and control. Recent experimental evi-

[1] Unless otherwise indicated, the information in this bulletin is largely based upon investigations conducted as a cooperative project between the Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Plant Pathology of the Maine Agricultural Experiment Station and on investigations and reports in the literature cited in the following publications. Such results of this cooperative investigation as are included herewith have already been published in different form, as follows:

Schultz, E. S., and others. Investigations on the mosaic disease of the Irish potato. *In* Jour. Agr. Research, v. 17, p. 247–274, illus. 1919.

——— and D. Folsom. Transmission of the mosaic disease of Irish potatoes. *In* Jour. Agr. Research, v. 19, p. 315–338, illus. 1920.

——— ——— Leaf-roll, net-necrosis, and spindling-sprout of the Irish potato. *In* Jour. Agr. Research, v. 21, p. 47–80, illus. 1921.

——— ——— Transmission, variation, and control of certain degeneration diseases of Irish potatoes. *In* Jour. Agr. Research, v. 25, p. 43–118, illus. 1923.

——— ——— Infection and dissemination experiments with degeneration diseases of Irish potatoes. Observations in 1923. *In* Jour. Agr. Research, 1924.

Folsom, D., and E. S. Schultz. The importance and natural spread of degeneration diseases in commercial Maine potato fields. Maine Agr. Exp. Sta. Bul. 316. 1924.

dence on this group of diseases shows that the so-called running out, deterioration, senility, etc., of the potato is caused very largely, if not entirely, by these virus diseases. Even though additional knowledge regarding these diseases is essential before complete control measures can be recommended, it is considered desirable to present at this time information which will be helpful in the production of better seed potatoes.

The growers of seed potatoes should know, among other things, that certain potato maladies are carried by insects, that degeneration of potatoes is largely due to these insect-borne diseases, that it is not wise to try to develop and maintain healthy stock by planting it adjacent to diseased lots, that tubers from diseased plants propagate the disease, that the selection of tubers without field inspection will not lead to the production of disease-free stock, and that cer-

FIG. 1.—Plants of the Green Mountain variety: (*A*) Healthy plant; (*B*) plant affected with mild mosaic. Mild mosaic is recognized by distinct mottling, slight dwarfing, wrinkling, and some ruffling of the leaves. Mottling is produced by more or less irregular light-green areas on the dark-green leaves.

tain practices of isolation of seed fields or plats coupled with special field inspection and the removal of diseased plants have been helpful in reducing the percentage of disease.

Since the cause of these degeneration diseases has not been demonstrated they are frequently called virus diseases, the term virus including whatever causal agents may be found later. The separate diseases have been named according to symptoms.

MOSAIC

APPEARANCE

Mosaic, so-called on account of the mottled foliage it produces, is recognized on the foliage by light-green and dark-green patches with more or less vaguely defined outlines. Three types of mosaic, mild, rugose, and leaf-rolling, have been observed on the potato.

In mild mosaic distinct mottling, slight dwarfing, wrinkling, and some ruffling of the leaves are characteristic symptoms (figs. 1 and 2).

Leaf-rolling mosaic resembles mild mosaic in slight dwarfing, slight ruffling, and wrinkling. It differs from mild mosaic in the characteristic rolling, mainly of the upper leaves, and in diffused mottling (fig. 3).

FIG. 2.—Leaf from a mosaic plant of the Green Mountain variety. Note the mottled, wrinkled, and ruffled leaflets

Rugose-mosaic symptoms are very distinct dwarfing, diffused mottling, a rugose type of wrinkling, and a tendency to show brittleness, spotting, streaking, and leaf dropping (figs. 4 and 13).

Mosaic mottling is modified by climatic conditions. In the northern seed-growing localities it is usually more distinct during the early part than the later part of the season. When seasonal condi-

tions, usually hot and more or less dry, continue during the entire growing season in these northern sections, it is very difficult to detect mosaic mottling. Under such unfavorable conditions mosaic can be recognized only in the types showing distinct dwarfing, ruffling, and wrinkling of the foliage. However, the fact that under unfavorable conditions mottling may be absent does not indicate that such plants are free from the disease, since experiments with mild-

FIG. 3.—Leaves showing leaf-rolling mosaic in the Green Mountain variety. Leaf-rolling mosaic resembles mild mosaic in slight dwarfing, slight ruffling, and wrinkling. It differs from mild mosaic in the characteristic rolling, especially of the upper leaves, and in diffused mottling.

mosaic potatoes have demonstrated that such plants or their progeny will show the mottled symptoms if again placed under conditions favorable for the development of mottling.

The most favorable environment for mosaic mottling obtains in the cooler localities of the humid regions, which are also very favorable for the best development of the potato. Under such conditions the inspection and elimination of mosaic plants can be accomplished more effectively than in the arid sections, where the mottled symptoms usually are masked. Mosaic symptoms are likewise somewhat varied on different varieties of potatoes.

OCCURRENCE AND EFFECT ON YIELD

Mosaic has been reported from all the important potato sections in this country. Different amounts of mosaic, varying from a trace to 100 per cent, have been observed in the different seed-producing localities.

Mild mosaic causes a reduction in yield frequently amounting to 15 to 30 per cent less than the product from an equal number of healthy plants (fig. 5). Plants infected with rugose mosaic or with the types of mosaic causing severe dwarfing very frequently produce only culls.

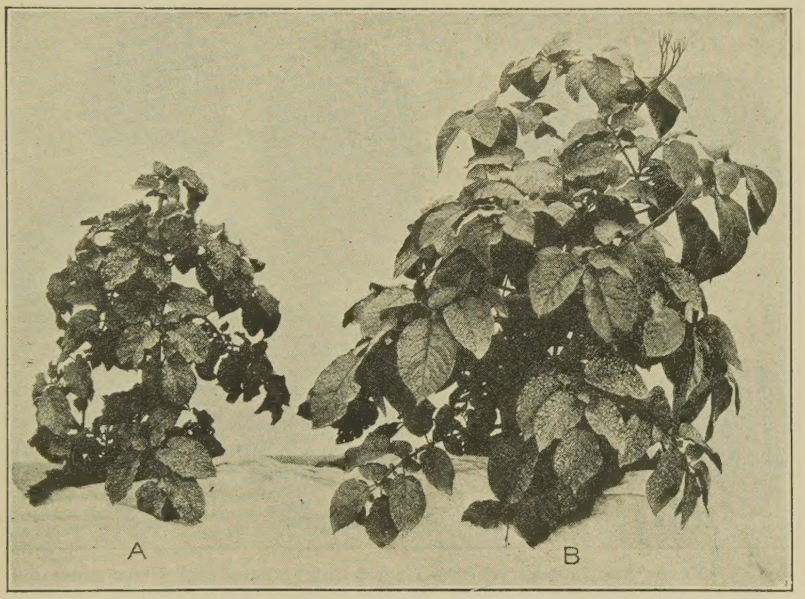

FIG. 4.—Plants of the Irish Cobbler variety: (*A*) Rugose mosaic plant; (*B*) healthy plant. Rugose mosaic is recognized by dwarfing, diffused mottling, and a rugose type of wrinkling. Such diseased plants are considerably more dwarfed than those affected with mild mosaic. Both plants show traces of Bordeaux spray

LEAF-ROLL

APPEARANCE

Leaf-roll is distinguished by the upward rolling of the leaves, so that the midrib remains at the middle of the trough thus formed. Plants becoming infected with leaf-roll while very young or plants from tubers infected with leaf-roll show rolling at first on the lower leaves, followed by rolling of progressively higher leaves until all leaves may be rolled later in the season. Plants infected late in their development may show rolling only in the upper leaves. Other symptoms of leaf-roll include dwarfing, rigidity, leathery texture, uprightness, chlorosis, yellowish, reddish, or purplish discoloration of the affected leaves, shortness of stolons, and reduction in number and size of tubers (fig. 6). A netted discoloration of the inside

tissues of the tubers called "net necrosis" is a symptom of leaf-roll in certain varieties.

The leaf-roll here described must not be confused with the rolling of the leaves produced by the following agencies and conditions: Symmetrical rolling of the leaves, due to insect injuries; rolling of the flabby and wilted leaves on plants affected with wilt; rolling of the leaves accompanied by a yellowish color on stalks showing a blackened discoloration at the base, due to black-leg; rolling of the leaves on plants subjected to excessive moisture conditions, as in localized exceptionally wet areas or during prolonged periods of rain, when practically all the plants in such areas may show rolling

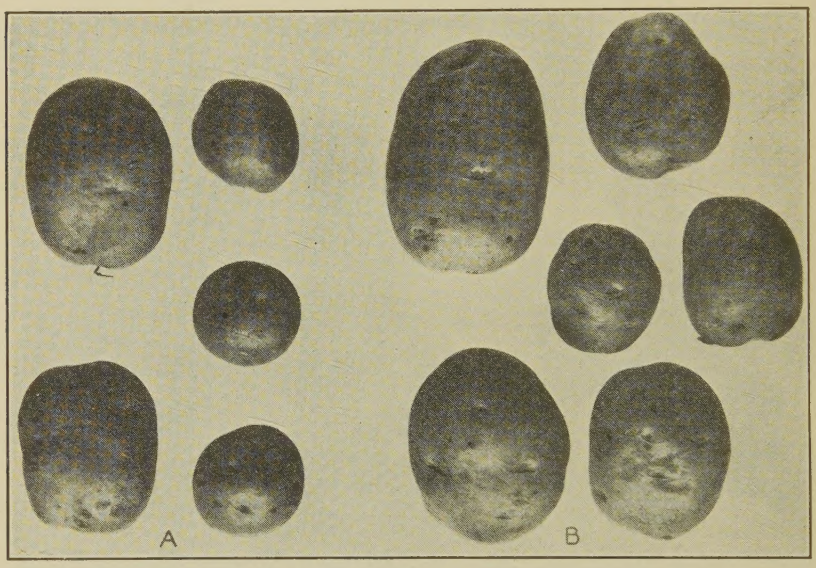

FIG. 5.—Mosaic and healthy progeny from 2-stalk hills of the Green Mountain variety: (*A*) Progeny from mosaic hill, 1.13 pounds; (*B*) progeny from healthy hill, 2.13 pounds

and a more general appearance of rolling than usually obtains in true leaf-roll; and rolling of more or less flaccid leaves at the base of the stalk, due to hot dry weather.

Leaf-roll thus is easily distinguished from mosaic. Frequently, however, the two diseases are present on the same plant, resulting in more severe dwarfing than with either leaf-roll or mosaic alone.

OCCURRENCE AND EFFECT ON YIELD

Leaf-roll, like mosaic, has been reported from all the important seed-potato producing sections in this country. It has been observed in percentages ranging from a trace to more than 50 per cent. The reduction in yield caused by leaf-roll is greater than with mild mosaic. Both the number and size of tubers are reduced, so that leaf-roll hills frequently yield from 40 to 70 per cent less than healthy plants, and where net necrosis is associated with leaf-roll merely culls or no yield may result.

SPINDLE-TUBER

APPEARANCE

Spindle-tuber, so called on account of the spindle-shaped tubers produced, is commonly designated by potato growers by such terms as "running-out," "running-long," "off-shape," or "poor-shape." Additional characteristics of spindle-tuber are more or less spindling and upright stalks, somewhat smaller and slightly darker green leaves than on healthy plants, and the tubers, instead of being flat oblong, as in healthy plants, are characteristically spindle shaped or cylindrical and with more conspicuous eyes than in the normal tubers (figs. 7, 8, and 9). In the red Bliss Triumph spindle-tuber also produces a lighter red color than is found in the healthy tubers.

FIG. 6.—Leaves showing leaf-roll on the Green Mountain variety. Note the rolling of the leaves at the base of the stalks and the rigid condition of the foliage

OCCURRENCE AND EFFECT ON YIELD

Spindle-tuber occurs in the chief commercial varieties. From none to 95 per cent of spindle-tuber infection has been found in some of these varieties. The distribution of this disease is not fully known, but according to reports from some of the large seed-growing sections in this country it may be assumed that it occurs wherever the potato is grown. Reductions in yield amounting to 25 to 50 per cent may occur. In addition to reduced yields, spindle-tuber renders the shape of the tubers undesirable for first-grade marketable stock, so that it is even more detrimental to the potato industry than mild mosaic.

STREAK

APPEARANCE

Streak produces streaking, spotting, burning, brittleness, leaf dropping, and premature death, but no mottling with the exception of chlorotic spots in areas where very soon spotting and streaking

appear (fig. 10). In current-season infections these symptoms may appear only on a single shoot in a hill and sometimes apparently affecting the leaves on only one side of such shoots; later in the season other shoots in the same hill may show these symptoms. Infected stalks and petioles are exceedingly brittle, so that the leaves drop and frequently remain suspended at the base of the petiole. The tubers from plants infected early in the season remain small. Second-generation plants remain severely dwarfed, curled, and streaked and frequently die before tuber formation.

OCCURRENCE AND EFFECT ON YIELD

Streak has been observed in some of the important seed-potato growing sections. However, the percentage of diseased plants is not

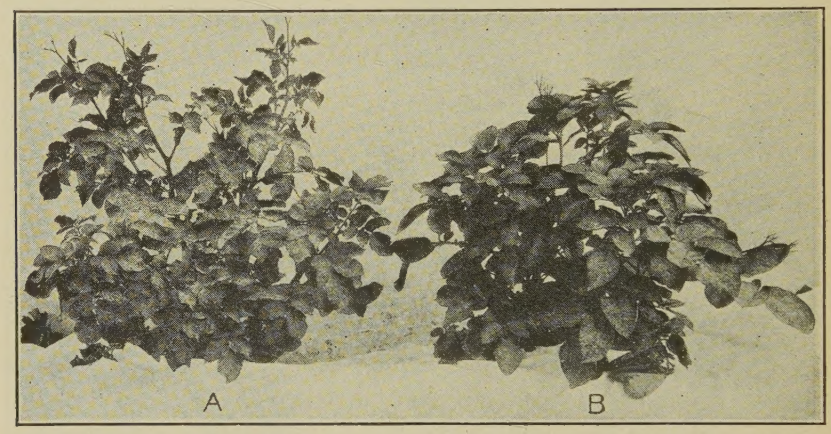

FIG. 7.—Plants of the Green Mountain variety: (*A*) Spindle-tuber plant from a half-tuber seed piece; (*B*) healthy plant from a quarter-tuber seed piece. The spindle-tuber plant, from the same seed tuber as the healthy plant, became diseased in the same season as the result of grafting a spindle-tuber seed piece on a healthy tuber seed piece. Note the more spindling, upright, and slightly smaller leaf character of the spindle-tuber plant than appears in the healthy top

so large as in mosaic and leaf-roll. This no doubt is due to the fact that tubers from streak plants produce very severely dwarfed shoots, which usually die prematurely before tuber formation.

CURLY-DWARF

APPEARANCE

Curly-dwarf is characterized by very distinct dwarfing, uprightness, spindling, curling, wrinkling, some rolling, slight ruffling, brittleness, burning, and somewhat premature death of the foliage. Curly-dwarf plants produce small, spindling, gnarled, and frequently cracked tubers (fig. 11). These symptoms suggest that this disease may be the result of spindle-tuber combined with one of the mosaic types. If so, the mottling has been eliminated in the combination.

OCCURRENCE AND EFFECT ON YIELD

Since the symptoms of curly-dwarf suggest that it may be a result of spindle-tuber combined with one of the mosaic types of dis-

ease, it may appear wherever these separate diseases occur. Curly-dwarf plants usually produce small and poorly shaped tubers, suitable only for culls. Hence such plants mean practically a total loss to the grower.

COMBINATIONS OF DISEASES IN A SINGLE PLANT

Two or more of these diseases may occur on a single plant, frequently producing severe dwarfing. Such dwarfed plants have been called "mosaic-dwarf," "bad mosaic," "mottled curly-dwarf," etc. The symptoms of the single diseases usually can be recognized in these combination infections. Plants having more than a single dis-

FIG. 8.—Plants and tubers of the Spaulding No. 4 variety: (*A*) Healthy plant and corresponding tuber progeny; (*B*) spindle-tuber plant and corresponding tuber progeny. The spindle-tuber plant has more upright, more spindling shoots and smaller leaves than the healthy plant. Note that the spindle-shaped tubers have more conspicuous eyes than the healthy tubers

ease (with a few exceptions, like streak) show more severe dwarfing than those affected with one malady (figs. 12 and 13).

From the results of disease transmission by plant lice reported later it will be apparent that disease combinations may easily result in fields where more than one of these diseases occur. It is evident that continued propagation of such plants will in severe cases produce considerable reductions in yield.

WHAT CAUSES THESE DISEASES?

The cause of these diseases has not been demonstrated. It has been found that the causal substance is carried in the juice of the diseased plants. Many tests have been made by treating healthy plants with juice from diseased foliage, with the result that the plants so treated became diseased. Healthy plants have been infected by grafting diseased stalks on healthy stalks, by grafting

diseased tubers on healthy tubers, by rubbing diseased juice into the leaves of healthy plants, and by transferring or allowing plant lice to feed on healthy plants after they have fed on diseased plants.

DISEASES NOT DUE TO CULTURAL OR CLIMATIC CONDITIONS

In view of the fact that these diseases can be transmitted from diseased to healthy plants it is perfectly clear that they are not caused by poor soil conditions, by too much fertilizer, by unbalanced fertilizer, by too much rain, by dry weather, by hot weather, or

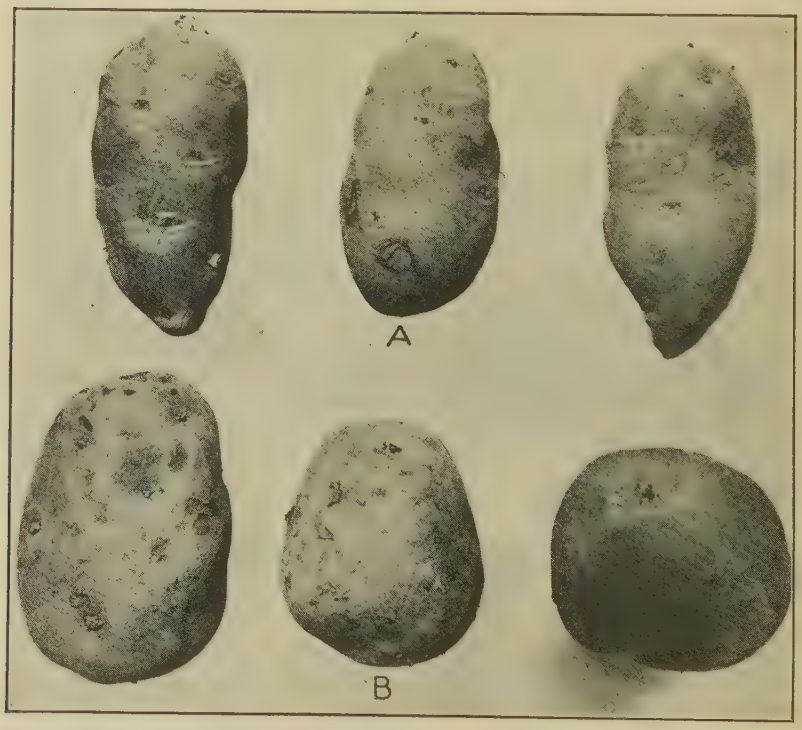

FIG. 9.—Tubers of the Green Mountain variety: (*A*) Spindle tubers; (*B*) healthy tubers

any similar condition. As has been stated previously, it is a fact that mosaic mottling may be rendered less evident during hot and dry seasons, but this is merely a response of mosaic to these conditions and not a case of cure, for such a plant still is diseased with mosaic, even if the mottling is made somewhat indistinct on account of unfavorable conditions.

Environmental factors affect the development of diseases, but such factors must not be mistaken for the cause of diseases.

SOIL DOES NOT HARBOR MOSAIC

No increase in mosaic has been found in healthy plants grown on soil on which 100 per cent of mosaic plants was grown the previous

FIG. 10.—Streak on a potato seedling. Note the small areas, somewhat along the veins, producing a streaked appearance. In early stages the dead spots may be more or less circular, but become irregular in outline and extend along the veins, causing streak. Streak also occurs on stems and petioles, which in advanced stages are very brittle

season or on soil to which an extra lot of mosaic tops had been applied, as compared with the same stock of potatoes grown on soil cropped with healthy stock the previous season.

TUBERS FROM DISEASED PLANTS PRODUCE SICK PLANTS

It has been demonstrated many times that the tubers from plants affected with mosaic, leaf-roll, spindle-tuber, curly-dwarf, and streak always produce diseased plants. Tubers from apparently healthy plants grown in the same field with diseased plants may also develop diseased tops. The cause of this will be discussed under the next heading.

FIG. 11.—Curly-dwarf of the Green Mountain variety. Note the dwarfed, spindling, upright, and bushy character of the tops, with the leaves slightly rolled, ruffled, wrinkled, and curled downward at the tips

PLANT LICE, OR APHIDS, CARRY DISEASES.

Experiments have proved that mosaic, including the mild, rugose, and leaf-rolling types, leaf-roll, spindle-tuber, and curly-dwarf, are carried from diseased to healthy plants by plant lice. By sucking the juice from the sick plants these insects at the same time obtain the "virus" or disease-producing agent, which they introduce into the healthy plants as soon as they commence to feed on them. Under favorable conditions plant lice multiply very rapidly, so that large numbers will disperse from one plant to another, thereby spreading these diseases. Consequently, the larger the number of diseased plants among healthy ones, the more favorable will be the conditions for spreading these diseases.

EVIDENCE PROVING THAT PLANT LICE TRANSMIT THESE DISEASES

Experimental evidence shows that healthy plants will develop mosaic mottling within a month after plant lice carrying diseased juice begin to feed on them. Similar results have been obtained with leaf-roll, spindle-tuber, and curly-dwarf. Such infection ex-

periments have demonstrated that 100 per cent diseased plants may be caused by plant lice moving from diseased to healthy plants.

INSECTS BESIDES APHIDS MAY TRANSMIT DISEASES

Since aphids have been demonstrated to be active agents in transmitting these diseases, it may be surmised that other insects also might carry them. Evidence in this connection has been reported from Ireland,[2] where preliminary tests indicate that some of the plant bugs and leaf hoppers may transmit potato leaf-roll, but this has not yet been confirmed in America.

FIG. 12.—Plants of the Green Mountain variety, showing rugose mosaic and spindle-tuber in combination and a healthy hill: (*A*) Hill showing combined effects of rugose mosaic and spindle-tuber; (*B*) a healthy hill

OTHER PLANTS BESIDES POTATO HARBOR MOSAIC

Other plants in the same family as the potato have been infected with potato mosaic; as an example of this nightshade may be mentioned. It is possible that still other species will be found as hosts of mosaic and of the other virus diseases of the potato. Even though it has been demonstrated that potato mosaic may infect other plants, it has not been proved that such plants necessarily serve as sources of infection. Observations indicate that diseased potato plants are the chief source of infection.

HILL SELECTION NEAR DISEASED PLANTS IS NOT RELIABLE

Healthy hills selected near mosaic plants when aphids are present will result in a high percentage of diseased progeny the following

[2] Murphy, P. A. Investigations on the leaf-roll and mosaic diseases of the potato. *In* Dept. Agr. and Tech. Instr. Ireland Jour., v. 23, pp. 20–34, illus. 1923.

season. It has been shown that such apparently healthy hills may produce plants with 84 per cent mosaic the following year. Similar results have been obtained with healthy hills selected near spindle-tuber plants (fig. 14). This emphasizes clearly the inadvisability of trying to develop disease-free potatoes by the selection of healthy hills from fields with a high percentage of diseased plants.

FIG. 13.—Plants and tubers of the Green Mountain variety, showing rugose mosaic and spindle-tuber in combination and rugose-mosaic hills: (*A*) Hill showing the combined effects of rugose mosaic and spindle-tuber. Note the dwarfing and the spindle-shaped tubers. (*B*) Hill showing the effect of rugose mosaic. Note that the dwarfing is less than in the plant shown in *A* and the absence of spindle-shaped tubers.

PLANTS FROM HEALTHY SEED POTATOES GROWN IN FIELDS ADJOINING DISEASED FIELDS MAY BECOME DISEASED

It is clear that mosaic, spindle-tuber, and similar diseases may spread very readily to near-by healthy plants. Observations on healthy stock grown in commercial fields adjoining fields having a high percentage of mosaic plants show that such healthy stock may in one season become infected with as many as 58 per cent of mosaic plants. In large fields with healthy stock adjoining diseased stock, the percentage of mosaic decreases as the distance from such diseased fields increases.

TUBER SELECTION IN THE BIN IS UNRELIABLE FOR THE PRODUCTION OF HEALTHY PLANTS

Tubers grown from mosaic, leaf-roll, and spindle-tuber plants (spindle-tuber being a result of late current-season infection) can not be distinguished from healthy tubers. The shape and size (with exceptions as noted later) of tubers from diseased hills may be like those of tubers from healthy hills.

The average size of tubers from diseased plants usually is smaller than that from healthy plants. However, there always are tubers of uniform size in both diseased and healthy lots, which makes the elimination of all diseased tubers impossible.

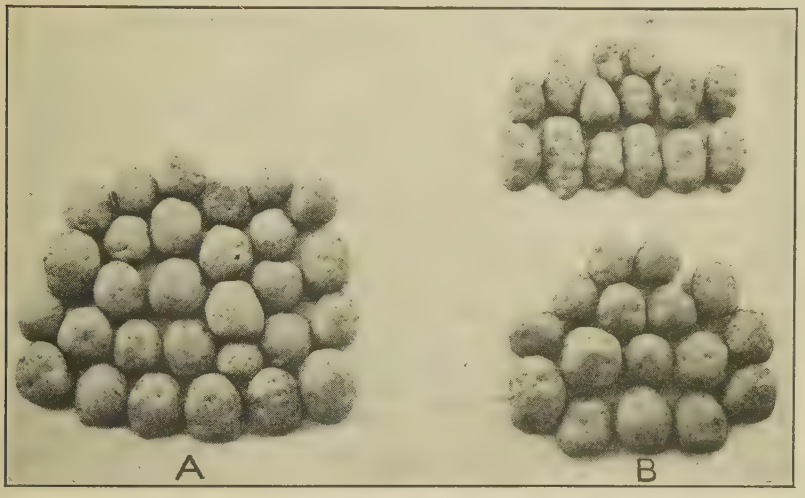

FIG. 14.—Healthy lots of the Green Mountain variety grown near spindle-tuber stock which became diseased with spindle-tuber: (*A*) Twenty-nine healthy tubers from as many tuber units representing stock grown during the previous season 10 rows from spindle-tuber plants; (*B*) 16 healthy and 14 spindle tubers from as many tuber units representing stock grown in the same field as during the previous season five rows from the spindle-tuber plants.

Since spindle-shaped (also called "poor-shape," "off-shape") tubers develop spindle-tuber plants, it is possible to reduce the percentage of such plants by discarding such tubers from seed potatoes. This, however, does not insure a crop free from this disease, since the late-season infection of healthy plants in the field the previous season may introduce spindle-tuber into good-shaped tubers which will develop spindle-tuber plants if used for seed.

The presence of a considerable percentage of spindle tubers is a very good index to the grower that such stock is undesirable for seed purposes. Disease-free stock should be substituted.

SPRAYING FOR MOSAIC AND SIMILAR DISEASES

Since experience has shown that a few aphids can transmit mosaic and similar diseases, and since spraying has not controlled all these insects, control of these diseases can not be attained by spraying.

However, since it has been shown that aphids can be reduced sufficiently by spraying with a contact insecticide to inhibit direct foliage injury, and since with reduced numbers of these insects disease spread may be expected to be checked somewhat, it is suggested that a contact insecticide be applied when aphids are numerous. A commonly recommended spray formula for aphids is three-fourths pint of nicotine sulphate to 50 gallons of Bordeaux mixture. This should be applied with a high pressure (200 to 300 pounds) sprayer, using at least three nozzles per row and with nozzles adjusted so that the spray will be forced against the insects as much as possible. Nicotine dust applied under favorable conditions has been reported to produce good results. The first application should be made when the first aphid migrations appear.

SEED TREATMENT

Treating potato tubers will not control mosaic or other insect-borne diseases, the cause of which, as stated before, is found in the juice within the tubers. Treating tubers with corrosive sublimate or formalin according to the formulæ given in Farmers' Bulletin 1367, "Control of Potato-Tuber Diseases," will kill the germs of black-leg, Rhizoctonia, and common scab on the surface of the tubers. Although this treatment has inhibiting effects on these germ diseases, it does not insure a crop of tubers free from Rhizoctonia and common scab, since, as is well known, these germs also live in the soil, from which, under favorable conditions for their development, the new tubers become infected. Under different conditions in the various potato-growing sections, various results with these seed-tuber treatments will be obtained, and control measures best adapted to the respective localities will be developed in each section.

ARE THERE IMMUNE VARIETIES?

It would be very fortunate indeed if varieties immune to these virus diseases could be found or developed by breeding. Observations indicate that the leading commercial varieties are susceptible to one or more of these insect-borne diseases. From investigations on this important problem, the Minnesota Agricultural Experiment Station in 1921 reached the following conclusion: "During the last 34 years all named varieties of any commercial importance found in the United States and a large number of foreign varieties have been tested. No varieties have been found to be immune from mosaic-dwarf. Selections failed to isolate resistant strains within varieties."[3] This significant experience emphasizes the importance of improving our commercial varieties by removing the diseased plants from partly diseased stock and maintaining disease-free stock by means of disease control, as suggested here.

[3] Krantz, F. A., and G. R. Bisby. Relation of mosaic to running-out of potatoes in Minnesota. Minn. Agr. Exp. Sta. Bul. 197, p. 29. 1921.

EFFECT OF ROGUING ISOLATED FIELDS

Experience has shown that it is impracticable to try to develop disease-free stock by removing diseased plants from plats adjacent to diseased potato fields. However, it has been found that by roguing more or less isolated lots having about 5 per cent of disease it was possible to reduce mosaic in such stock to 1 or 2 per cent.

Such experiences suggest the advisability of securing from reliable sources practically disease-free stock and planting it in an isolated field or plat. By careful field inspection and roguing it has been possible to keep the percentage of diseased plants in such stock within 1 per cent.

In certain sections in northern Maine where small fields are partly surrounded by woods and by a river, healthy potatoes have been maintained practically free from mosaic and similar diseases for three seasons.

In other northern localities it has been shown that careful inspection and roguing of isolated fields resulted in the production of practically disease-free seed potatoes.

ISOLATED SEED FIELD OR PLAT

PLANT IN ISOLATED FIELDS SEED POTATOES FREE FROM MOSAIC AND RELATED DISEASES.

Location.—The field should be located as far as possible from the nearest field where diseases of the potato occur. The distance these diseases are carried naturally varies under different conditions. In northern Maine it has been found that in the same season in certain fields mosaic spread beyond 150 feet, while in other fields it spread barely 30 feet.

ROTATE TO PREVENT DISEASED VOLUNTEER PLANTS FROM INFECTING NEW CROP.

Potatoes should be rotated with other crops so that volunteer plants harboring disease will not become a source of infection to the new crop.

Source of seed tubers.—Seed tubers should be secured from sources where practically disease-free plants are grown. Potato-seed inspection and certification officials can furnish information regarding the best sources in the respective localities. It is, of course, important that such seed stock be grown in fields isolated from diseased fields; otherwise, apparently healthy stock may produce many diseased plants the following season.

Method of planting.—Field inspection and roguing will be facilitated if but one seed piece per hill is planted. Machine planters should be so operated that, so far as possible, only one seed piece per hill is dropped.

Growers who desire to have small isolated plats will find inspection and roguing more easy and effective on tuber-unit seed plats than on

those planted by machine. This, of course, means planting by hand. The tubers are cut at the time the seed pieces are dropped in the open furrow previously made by a machine. Between tuber units a skip of one seed piece is made, so that the plants from each tuber can readily be detected during field inspection and roguing. The crop from such plats can then be used for planting the commercial field the following season.

ROGUE ALL ABNORMAL PLANTS. BEGIN WHEN DISEASE APPEARS.

Inspection and roguing.—Inspection and roguing of isolated fields should be done at least three times during the season. The first roguing should take place when the plants are not more than 6 inches above ground. Mosaic mottling in the Northern States usually appears more plainly at this period than later in the season. Furthermore, early roguing will prevent aphids from transmitting diseases from sick to healthy plants later in the season. Early roguing when aphids are few will also tend to produce less infection by fewer insects falling from rogued plants while being taken from the field than would occur later when aphids are more numerous.

The second roguing should follow about 10 days after the first, and the third roguing about two weeks after the second. If any varietal mixtures are present the field or plat should be inspected during blossoming time, when such plants can best be detected and removed.

During these field inspections all diseased plants, including tops, seed pieces, and new tubers, should be removed from the field or plat. All plants showing mosaic mottling or other abnormal symptoms, or dwarfing, wrinkling, rolling, spindliness, and streaking, should be carefully removed from the field and destroyed or deposited at least several hundred feet away from the field, so that any transmitting insects on the rogued plants may not produce new infections.

Spraying.—Bordeaux mixture combined with contact and poison sprays for the control of plant lice and other insects should be applied as soon as these pests appear and should be repeated as many times as seasonal conditions may require. (See Farmers' Bulletin 1349, "Increasing the Potato Crop by Spraying.")

Cultivation.—Keep potato fields free from all weeds, thereby providing favorable conditions for the growth of the crop and facilitating inspection as well as providing against the possibility that some weeds may harbor the virus diseases.

PRACTICE CLEAN CULTIVATION.

COOPERATIVE SEED-POTATO PRODUCTION

In view of the fact that one of the promising methods of producing disease-free seed potatoes consists in growing them in fields isolated from diseased stock, and since this is very difficult for

growers whose neighbors may have diseased stock, it is suggested that growers who are interested in the production of high-grade disease-free seed stocks cooperate with their neighbors in order to bring about a community interest.

If community cooperation can be secured to insure the planting of none but disease-free seed within the range of aphis spread—or approximately one-fourth mile from seed-potato fields—the problem will be much simpler.

The growing of one and the same variety or at most two varieties would also tend to simplify the production and maintenance of disease-free stock, and by growing such stock on a community basis the marketing problem could be handled more easily and economically.

Different communities should grow the variety or varieties which experience has shown to be best adapted for their section.

CERTIFIED SEED POTATOES

By carefully observing methods for the production of disease-free potatoes as indicated here many growers in the northern seed-potato-growing localities have succeeded in producing certified seed potatoes. Since experience has shown that planting these potatoes results in yields superior to carelessly selected commercially grown potatoes, careful buyers of seed potatoes demand certified stock, for which a premium is generally paid.

SUMMARY

Deterioration, or running out, of potatoes is largely caused by diseases.

Mosaic, leaf-roll, spindle-tuber, curly-dwarf, and streak are insect-borne diseases chiefly responsible for the so-called running out of potatoes.

These insect-borne maladies cause losses in yield ranging from 15 to 70 per cent and practically a total loss in severe cases.

Mosaic, leaf-roll, spindle-tuber, and curly-dwarf have been reported from important seed-potato-growing sections of the United States.

Plant lice carry mosaic, leaf-roll, spindle-tuber, and curly-dwarf from diseased to healthy plants. Other insects have been reported to transmit leaf-roll.

Experience indicates that mosaic and leaf-roll are not carried in the soil.

Transmission of mosaic, leaf-roll, spindle-tuber, and curly-dwarf from diseased to healthy plants has been demonstrated by means of tuber and stalk grafts and, with the exception of leaf-roll, by juice inoculations.

Tubers from diseased plants always produce the disease in the new plants.

Tubers from mosaic and leaf-roll plants can not be distinguished by their general appearance from those of healthy plants. The same holds true with tubers from an apparently healthy plant which contracted spindle-tuber late in the growing season.

Tubers from plants grown from spindle-tuber plants can be recognized by their spindle or "run-long" shape. A large percentage of such tubers is a good index of the undesirability of stock for seed purposes.

Hill selection of apparently healthy plants in fields having a high percentage of these insect-borne diseases where aphids and possibly other insect carriers are numerous will usually result in a crop with many diseased plants.

Bin selection of tubers from fields having a high percentage of these insect-borne diseases will result in a badly diseased crop.

Observations indicate that besides the potato other plants in the nightshade family as well as in other families harbor mosaic.

Observations have disclosed that mosaic mottling is modified by climatic conditions, but that such modifications are not an indication of freedom from disease in these plants.

Healthy stock planted beside or near potatoes having a high percentage of these insect-borne diseases when aphids and possibly other insect carriers are numerous will become diseased. Most of the symptoms of disease will appear in the next year's crop.

Experience has shown that it is impracticable to attempt the production of healthy seed potatoes by removing diseased plants from plats or fields adjoining those with a high percentage of diseased plants when aphids are numerous.

The leading commercial varieties of potatoes are susceptible to one or more insect-borne diseases. This emphasizes the importance of producing and maintaining healthy lots of these varieties for seed-potato production.

By careful field inspection and roguing under isolated conditions in certain northern localities, it has been possible to produce and maintain for a few seasons practically disease-free seed potatoes.

The isolated tuber-unit seed plat is recommended as an aid in the improvement of seed potatoes. It is suggested that the production and maintenance of disease-free seed stock can be accomplished very advantageously by the close cooperation of interested growers in community groups.

Careful inspection of the plants during the entire growing season is more important than any single procedure for securing information regarding these insect-borne diseases. At that time it is possible to detect these maladies, so that diseased plants can be removed, as is done in the seed field or plat, or in case of a high percentage of disease the stock can be condemned for seed purposes.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

October 10, 1924

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